Application of resistivity monitoring to examine the grouting effect

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Abstract: This paper presents to examine the ability of an electrical resistivity method to monitor the grouting effect at subsidence area. To monitor the changes in ground resistivity before and during the grout, series of electrical resistivity monitoring surveys have been conducted. Data has acquired in the form of grid making nine lines parallel to road and four lines traverse the road. Two kinds of electrode arrays modify pole-pole and dipole-dipole arrays were used during resistivity data acquisition. In this paper, the results show that electrical prospecting is an effective method to detect low resistivity imaging zone by grout during the ground reinforcement.

Key words: resistivity monitoring, grouts, ground reinforcement, subsidence

1. Introduction

In 2005 different geophysical methods such as electrical resistivity, microgravity and MASW (multichannel analysis of surface waves) were used to investigate the subsurface geology structure at Yongweol-ri, Muan-gun. Cavities are found in the survey area, these cavities are widely present within the limeslicate bedrock. And limeslicate cavities mostly filled with groundwater and clays. These buried cavities might lead to road collapse and is thus serious threat to human safety (park, et al., 2005).

One common and simple technique is used to stabilize the subsurface and prevent subsidence to use cement based grout to fill the cavity below. The grout material was injection into cavities or rock formations, in order to improve their properties, specifically to reduce permeability, to increase strength and durability. In the survey area drilling was carried out along the road between line 4 and 5, to install pipes that connect the surface to the voids below. The pipes act as conduits to the subsurface voids. Grout material is pumped under pressure and injected into the subsurface cavities.

To estimate the effect of grouting, the electrical resistivity survey has carried out in three phases, firstly before the grouting injection, secondly and thirdly during the grout injection. In this paper, using the resistivity measurements before and during the grout, significant changes in subsurface resistivity has been estimated. In addition, laboratory experiment is in progress to determine significant changes in mortar resistivity with time. Ruther discussing all of the survey results in this paper; we have focused our discussion on the results obtained from three lines.

2. Resistivity monitoring method

To monitor the changes in ground resistivity before and during the grout, surface resistivity survey has been conducted. Data is acquired in the form of grid making nine lines parallel to road and four lines transverse the road. Electrodes were installed with 5 m spacing and length of each line was about 100 m, filed site acquisition is shown in Fig. 1. Lines 4, 5 and 6 has been permanently installed in the monitoring area while the rest of the lines were located in cultivated land due to which it was difficult to install them on permanent basis. The electrode layouts used dipole-dipole and modify pole-pole arrays. Measurements were taken using a large number of electrodes installed on a prospecting line. These electrodes were connected to a resistivity measurement of the main unit using connection cables, and the potential difference was measured according to the installed electrode arrangement. The program DIPRO (Kim, 1987) was used to determine a two-dimensional resistivity model for the subsurface for the data obtained from the electrical resistivity prospecting. In this automatic analytical method, a forward modeling subroutine was used to calculate the apparent resistivity values, and a non-linear least-squares optimization technique used for the inversion routine.

Monitoring system is categorized into three different phases. The first set of measurement of resistivity data, which is phase 1 of monitoring survey, were collected on February 03, 2006, before the grout started operation. On March 07, 2006, we acquired the second set of resistivity measurement in phase 3, during the grout injection. On April 04, 2006 we acquired the third set of resistivity measurements in phase 4, during the grout. In all, thirteen lines data have been acquired including parallel and cross lines. However, in this paper we have presented only dipole-dipole resistivity result of lines 1, 4 and 6 and their phase difference. Grout injection has been carried out along the both side of road between lines 4 and 5.

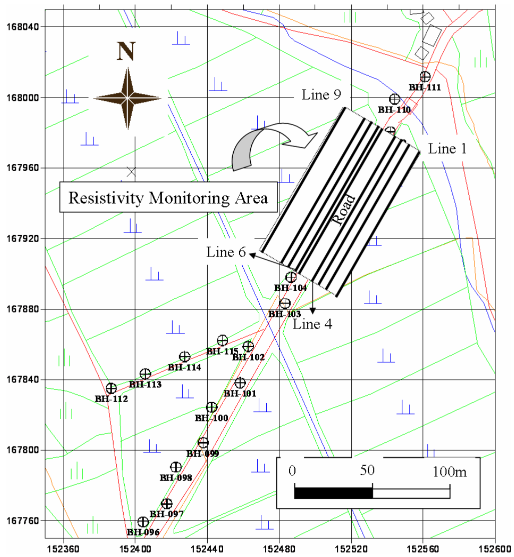


Fig. 1. Layout of the resistivity lines at field site.

3. Laboratory experiment

A laboratory study is designed to ascertain the significance change in mortar resistivity with time-lapse. Resistivity of mortar sample is measured by using Mini OHM of (OYO Co, Japan). We used four identical specimen 160 mm in length and 80 mm in internal diameters. The specimen and Mini OHM which were used for this study are shown in Fig. 2.

Four encircling electrodes were installed at 30 mm interval on each specimen. Each specimen was then filled up with mortar which was prepared in laboratory, having the same composition used at field site. Four specimens were exposed to two different environments. (a) Specimen 1 and 2 are exposed to air, (b) Specimen 3 and 4 are put inside water container.

Resistivity measurements were obtained on daily basis to determine change in resistivity with time. Significant change in resistivity has been observed between exposed specimen and inside water one. The specimen retained within air environment lost moisture and showed early cementation (solidification) due to which they exhibited rapid resistivity increase in earlier stage. On the other hand samples within water environment absorbed water and gradually started cementation (solidification) showing steady increase in resistivity with time-lapse. Time-lapse and resistivity graphs are shown in the Fig. 3.


Fig. 2. Apparatus used in laboratory test.

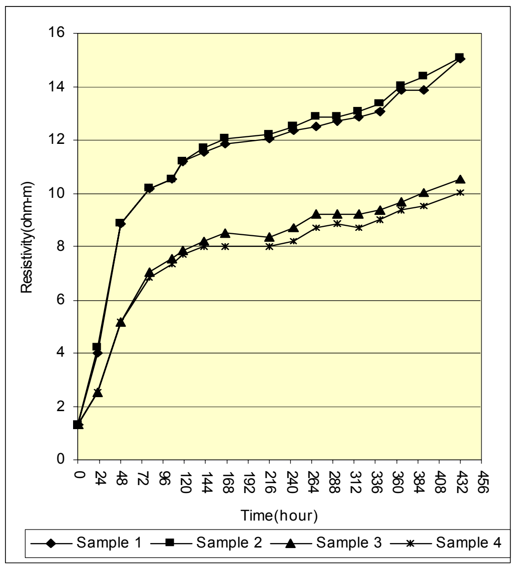


Fig. 3. Specimens 1, 2 and 3, 4 are exposed to air and in the water container, respectively.

4. Results and interpretation

Fig. 4 shows the resistivity distribution and difference of line 1 for before and during grouts injection. In Fig. 4(a) the thickness of top soil is 3-7 meters and its resistivity ranges from 50~80 ohm-m. Underlying the top soil is weathered rock, about 1.5~2 m thick where the resistivity ranges from 90~190 ohm-m. Underneath weather rock is limeslicate. In Fig. 4(b) and 4(c) yellow color signify that "no change in resistivity". In Fig. 4(b) slight increase in resistivity has been observed between 35~60 m in (horizontal direction) at depth of 5~7 m. Similarly Fig. 4(c) shows slight increases in resistivity between 10~20 m and 35~50 m in horizontal direction, at a depth of 6 m and 22 m respectively, and slight decrease in resistivity below the 20 m at the depth of 22 m. This change may be due to seasonal variation. Hence it can be concluded that no significant change in resistivity is observed before and during the grouting because line 1 is located at 35 m away from injection hole. Line 4 is permanently installed along the road. During the 3D resistivity survey at Yongweol-ri, Muan-gun, it was confirmed by drilling that weak zones and cavities were located near line 4 (Park et al., 2005).

The resistivity distribution and phase difference of line 5. In Fig. 5(b), no significant change in resistivity along the line 4 has been observed which might be an indication that the grouting material has not been injected along the survey line when the data has been acquired. In Fig. 5 (c) decrease in resistivity has been observed at (A1). As we are measuring mortar resistivity at laboratory scale, mortar showed very low resistivity but resistivity increased gradually with the passage of time. Hence it can be concluded from Fig. 5(c) that decreases in electrical resistivity (blue) is observed in the region where the grouting is injected. Line 6 is permanently installed along the road. As previous survey result predicted that weak zone is located in the region of line 4, 5, 6 and 7 (Park et al., 2005).

Fig. 6 shows the resistivity distribution and difference of line 6 for before and during grouts injection. In Fig. 6(b) slightly increase in resistivity is shown in the upper part ranging from 40~60 m in (horizontal direction) at the depth of 2~3 m and also increase resistivity below the 70~75 m in (horizontal direction) at the depth of 25 m. Increase in resistivity of upper portion might be due seasonal variation. In Fig. 6(c), decrease in resistivity is observed at (X1). We interpreted that decrease in resistivity (blue) is observed in the region where the grout is recently injected.

5. Conclusion

Main conclusion as drawn as a result of this study can be summarized as follows:

1. Decrease in electrical resistivity (blue) is observed in the region where the grout was recently injected.
2. The results suggest that electrical resistivity technique is an effective method to monitor grout injection.
3. Electrical prospecting method is an effective method to detect low resistivity imaging zone by grout for ground improvement.
4. The electrical resistivity of grouting material is lower than the surrounding rock but gradually increases with time.
5. Laboratory experiment indicates that resistivity of mortar increases with time.

To determine significant changes in mortar resistivity with time-lapse, monitoring work at laboratory scale and field site is in progress.

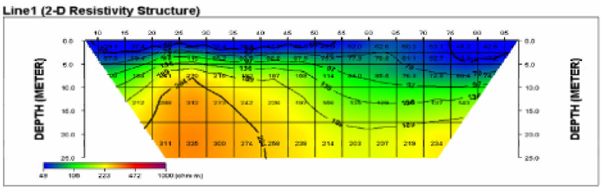
Reference

Jung-Ho Kim, Myeong-Jong Yi, Yoonho Song and Seung-Hwan Chung, 2001, A Study on the Modified Electrode Arrays in Two-Dimensional Resistivity Survey, Geophysical Exploration, Vol.5, No. 4, pp.206~216. (in Korean)

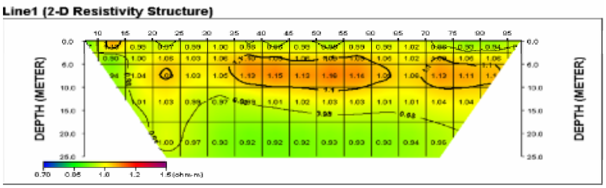
Kim, J.H., 1987. *Inversion of two-dimensional resistivity survey data*, Ph. D. thesis, Seoul national Univ.

Sam-Gyu Park, Jung-Ho Kim, Changryol Kim, Seong-Jun Cho and Jeong-Sul Son, 2005, Application of integrated geophysical methods to cavity detection at the ground subsidence area. Symposium on subsidence investigation, design and construction, KIGAM, pp. 71~85. (in Korean)

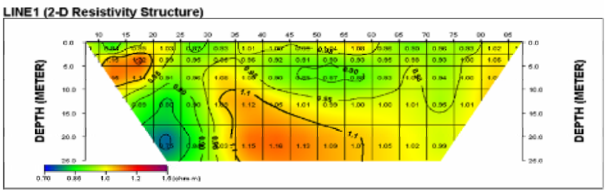
Mikyung Park, Hiroomi Nakazato, 2003, Laboratory study on exploration characteristics of low resistivity imaging zone by electrical resistivity prospecting. Proceedings of the 6th SEGJ Symposium, pp. 307~311.



(a) ER result for line 1 before grout

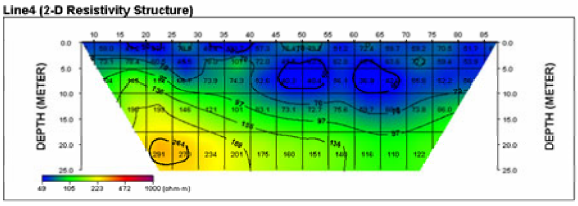


(b) Phase Difference (ph3/ph1) ER result for line 1 during grout

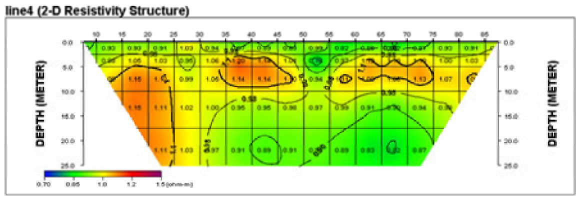


(c) Phase Difference (ph4/ph3) ER result for line 1 during grout

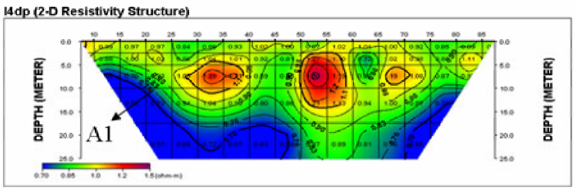
Fig. 4. Resistivity distribution and difference of line 1.



(a) ER result for line 4 before grout

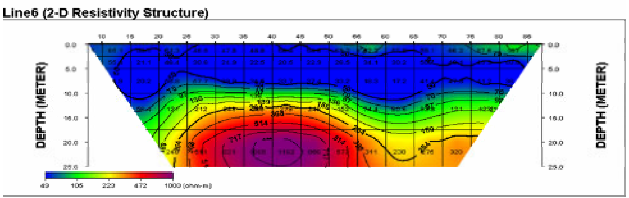


(b) Phase Difference (ph3/ph1) ER result for line 4 during grout

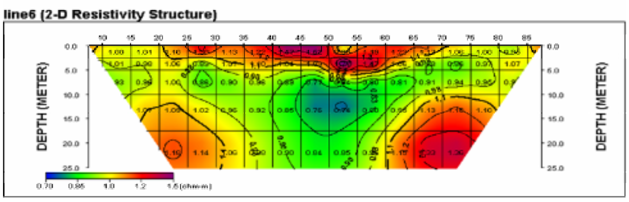


(c) Phase Difference (ph4/ph3) ER result for line 4 during grout

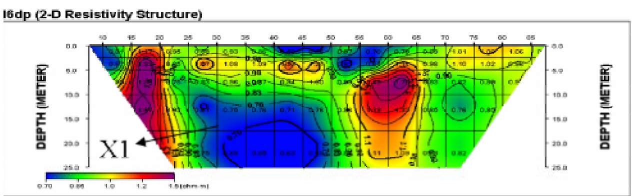
Fig. 5. Resistivity distribution and difference of line 4.



(a) ER result for line 6 before grout



(b) Phase Difference (ph3/ph1) ER result for line 6 during grout



(c) Phase Difference (ph4/ph3) ER result for line 6 during grout

Fig. 6. Resistivity distribution and difference of line 6.